Propagation Database Version 6.0

Reference Manual

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November 1999

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Foreword

The Propagation Models Database Software is intended to be a versatile tool for telecommunications systems engineers. Though every care has been taken to make the software easy to use so that it may serve a cross section of users, the authors would appreciate any comments or questions regarding its operation and capabilities. Please use the following information to communicate your comments, suggestions, and questions about the software:

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Acknowledgments

This Software and Manual were developed by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration (NASA). We would like to thank NASA for their support.

This version of the Propagation Database is based on previous versions which were created by Krisjani Suwitra Angkasa, and Chuong Le.

Anil Kantak, who has worked on every version of this software, also deserves praise for his knowledge of the Engineering behind this software. His suggestions and encouragement has been invaluable and many of the finer features of this program were made even better by his suggestions.

Nasser Golshan has been instrumental in helping with the overall organization of this project. His suggestions for the overall organization of this manual were particularly helpful, as well as his generous praise.

An honorable mention should go to Faramaz Davarian for reviewing the software ahead of time, searching for bugs, and offering helpful suggestions.

Introduction

The National Aeronautics and Space Administration's (NASA's) Propagation Program supports academic research that models various propagation phenomena in the space research frequency bands. NASA supports such research via schools and institutions prominent in the field. The products of these efforts are particularly useful for telecommunications systems engineers and researchers in the field of propagation phenomena.

The systems engineer usually needs a few propagation parameter values for a system design. Published literature on the subject, such as the Consultative Committee for International Radio (CCIR) publications, may help, but often the parameter values given in such publications use a particular set of conditions that may not quite include the requirements of the system design. The systems engineer must resort to programming the propagation phenomena models of interest to obtain the parameter values to be used in the system design. Furthermore, the researcher in the propagation field must then program the propagation models either to substantiate the model or to generate a new model. The researcher or the systems engineer must either be a skillful computer programmer or must hire a programmer. This, of course, increases the cost of the effort; an increase in cost due to the inevitable programming effort may seem particularly inappropriate if the data generated by the experiment is to be used to substantiate the already well established models, or a slight variation thereof.

To help the researcher and the systems engineers, it was recommended by the conference participants of NASA Propagation Experimenters (NAPEX) XV (London, Ontario, Canada, June 28 and 29, 1991) that a software package should be constructed that contains propagation models and the necessary prediction methods of most propagation phenomena. Moreover, the software should be flexible enough for the user to make slight changes to the models without expending a substantial effort in programming. The software described in this reference manual meets all the requirements described above.

Properties of the Database for Propagation Models

The Propagation Model Database described here creates a user-friendly environment that makes using the database easy for experienced users and novices alike. The database allows sufficient freedom for users to custom fit the propagation phenomena model of interest to their requirements. The database is designed to pass data through the desired models easily and generate relevant results quickly. The database contains many of propagation phenomena models accepted by the propagation community. Only minimal computer operations knowledge is necessary to run the database.

The models included in the database are published in the NASA Propagation Effects Handbook, CCIR publications, or other publications such as the IEEE Journal etc. Every model included in the software contains a reference to the document from which the model was obtained, and a brief description of the model itself. Also, when applicable, the related model names are also indicated. The parameters of every model in the database are shown explicitly, and the units of the parameters are defined completely so that the user does not have to invest time investigating them. Wherever possible, to make the use of the model obvious to the user, default values of the parameters are given. The default values are generally values that are used most frequently with the model, the user is free to change them to more appropriate ones for their run of the model. One possible use of the default values is to compare the already known results using the default values with the newly obtained values in an experiment.

Some propagation phenomenon models are long, and to include them as single steps would make use and understanding of the software quite difficult, if not impossible. To avoid this inconvenience, such models are broken down into several steps as appropriate, and parameters as well as outputs of each step are described in detail in every step. Although the software generates the relevant charts for the model under use, the users have at their disposal the extensive charting capabilities offered by Microsoft Excel Software to change the created chart if so desired. Where feasible, the actual charting process is made transparent to the user and involves the user only when a choice must be made between the possible outputs.

The database also allows the user to make changes, within some guidelines, to the model being run. The main restriction is that the user may change the form of the mathematical functions and operations in the model using only existing parameters of the model; new parameters may not be introduced within the equations. In general, this restriction is not detrimental to the usefulness of the model.

Every model in the database has the same operating procedure and instructions, thus the user needs to learn the procedure for only one model in order to use the entire database effectively. All the necessary precautions to ensure the correct use of the database are incorporated in the program. When incorrect inputs are made or when an action conflicts with the general directives of the program, the user is alerted with a warning and where possible suggestions are made to correct the fault.

Excel software has many functions available to the user such as curve fitting, statistical analysis etc., to make the data analysis easy. The database software employs user friendly procedures to call these functions from Excel's library so that the user may use them as needed with minimum efforts.

The database is provided to the user free of charge.

Hardware Requirements

To use this database, you need either a PC or Macintosh, and a copy of Excel version 95 or later

Installing

Windows:

- Insert the Disk Labeled "Propagation Database Version 6.0".
- If you are using Windows95 or WindowsNT 4.0, then click on the 'Start' button, then on 'Run'
- Type in the drive letter of the Floppy Drive, followed by the word 'Setup'
- A setup utility will guide you through the rest of the process
- When the program is installed, it can be accessed through the Menu Item labeled 'Tools' in Excel.

Macintosh:

- Insert the Disk Labeled "Propagation Database Version 6.0"
- When the Disk Icon "Propagation Database Version 6.0" appears, drag it to the icon representing your hard disk
- Double Click on the hard drive icon
- Double Click on the directory labeled "Propagation Database"
- Double Click on the file named "Propagation Models". This will add the functions to your excel add-ins list, and load the Models

Using the Models

This version of the Propagation Database (version 6.0) is comprised of 23 Models. These models are:

Tropospheric Models:
- Gaseous Attenuation Model
- Scintillation Model

Land-Mobile Models:
- Attenuation Frequency Scaling Model
- Cumulative Distribution of Fade Duration Model
- Diffusely Scattered Waves Model
- Empirical Roadside Shadowing Model
- Faraday Rotation Model
- Fresnel Zone Model
- Frequency Reuse Model
- Diversity Improvement Model
- Rayleigh Probability Density Model
- Reflection Coefficient Model

Maritime-Mobile Models:
- Fading Due to Sea Reflection Model
- Interference Prediction Model

Effects of Small Particle Models:
- Altshuler Fog Model
- ITUR Cloud Model

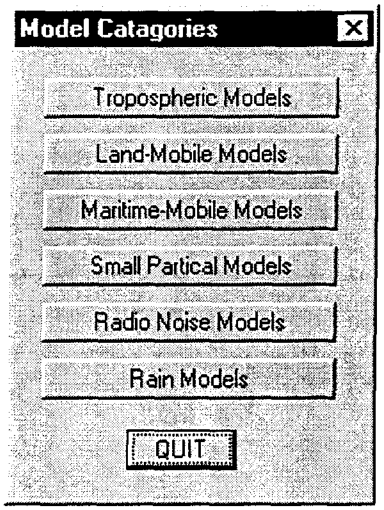
Radio Noise Model
- Radio Noise Model

Rain Models:
- ITUR Model
- COMSAT Model
- DAH (USA) Model
- Depolarization Model
- Global Model
- Site Diversity Model

Accessing the Models

To access the models, first you must load a file named Prop60.XLA. This can be done in one of three ways. First, the file can be loaded by double clicking it on a windows explorer program. Second, under Excel the file can be opened by clicking 'File' and 'Open' on the menu's, and selecting the file. The third method is to click on 'Tools' and 'Add-ins' on the Excel menu. Then click 'Browse' and select the file. If the third method is used, then the Propagation Models will automatically load each time Excel is started.

After the file has been loaded, the models can be accessed by clicking on the menu items 'Tools' and 'Propagation Models'. The following dialog box will then appear:



Entering Values and Getting Results

Some of the models are split into several steps. Each step has inputs and outputs separated by a vertical line. The inputs are on the left side of the dialog box, and the outputs are on the right side. As soon as the input values are changed, the outputs will automatically change according to the model. Many of the output values from one step are used as inputs to later steps. In order to make the model more flexible, some of these values were made to be overwritten. Values that can be overwritten are placed in editboxes similar to the input values. When changes are make to these values, the rest of the model will automatically calculate using the overwritten values.

In order to traverse the dialog box, use the tab key to go from one input field to another. Some of the models are too large to fit on one dialog box, so they are split into two dialog boxes. To go to the next dialog box on these models, click on the 'Next' button. A 'Prev ' button will be available on the second dialog box to return to the first if necessary.

Using Models in Excel Programs

The functions used in the Propagation Database are configured such that they may be used in any other Visual Basic application. Since each Model has different inputs, each function requires different parameters.

For most models, there are several outputs. In order to allow one to choose which output variable should be returned from a function, each function has an extra field called the Output Selector. This is a number that uniquely identifies the output value to be returned.

For example, to calculate the Total Attenuation from Gaseous Attenuation given a signal of 20 Ghz frequency passing though the atmosphere with 1000 hPa of pressure, 10°C temperature, 7.5 g/m^3 water vapor density, from a station .1 km from sea level to a satellite 80km over the Earth at an antenna elevation angle of 80° through rainy weather using the default modified Earth radius of 8500 km, you would need to type the following:

=Gaseous_Attenuation(20, 1000, 20, 7.5, 0.1, 80, 80, 8500, 1, 1, 4)

Note the 4 as the last variable, which is the number corresponding to the Total Attenuation in the Gaseous Attenuation Model. See the Gaseous Attenuation Help file for more details.

If a value for the output selector is not entered, the value returned will be the final result of the model, which in this case is the Total Attenuation. Therefore, the previous function is functionally the same as:

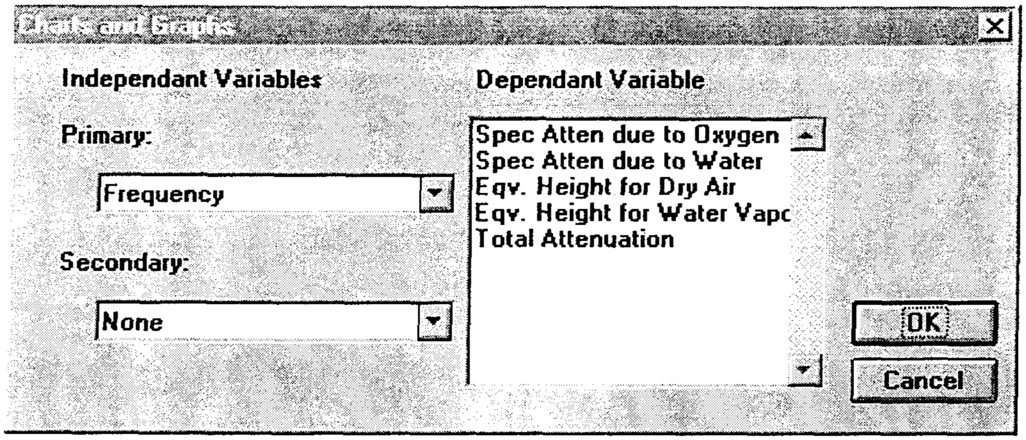
=Gaseous_Attenuation(20, 1000, 20, 7.5, 0.1, 80, 80, 8500, 1, 1)

To find out more about how to use a specific model, view the help file for that specific model.

All of these functions will work if entered in a cell on a worksheet, or in a function as part of a program. If any problems are encountered running the software or have any contributive suggestions, please notify us at PROPAGATION@ZORBA.JPL.NASA.GOV

Graphing

The Graphing feature on the Propagation Database have been vastly upgraded since version 4.0. One can now use the graphing functions to experiment with the effects of multiple independent variables on a dependent variable or variables. To use these graphing functions begin by selecting the model and then enter the values for each of the inputs; the outputs will calculate automatically. At the end of the model, there is a button labeled "Graph". With a click on this button, a dialog box similar to the following will appear:

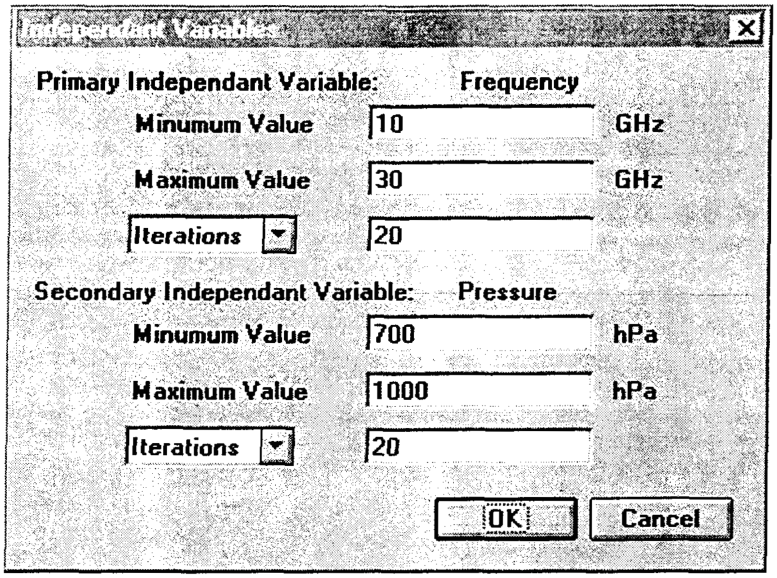


On the left side of the dialog box, there are two dropdown boxes that allow one to select the independent variables that will be used on the X and Z Axises of the Graph. The second dropdown box can be set to 'None' indicating that the graph will only have a single independent variable.

In the middle of the dialog box, there is a listbox that contains the names of the dependent variables of the model. One may select as many variables as possible to appear on the graph, however only one scale will appear on the graph, so if one function results in answers of a huge magnitude compared to the others, all other graphs will appear as flat lines near or at zero. This feature is not available on graphs with multiple independent variables.

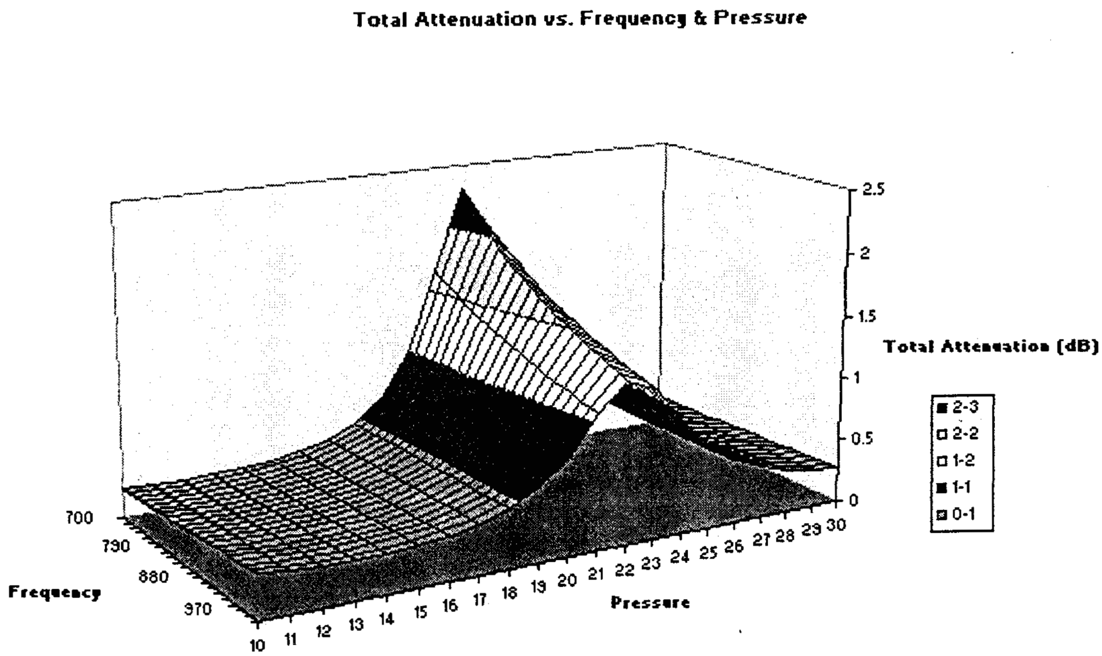
Note:
If an input box on the model was not filled with a value, then that variable must be selected as an independent variable.

After selecting the independent and dependant variables, click the 'OK' button, and another dialog box will appear. This new dialog will be similar to the following:



For each independent variable, there are two edit boxes with the labels "Minimum Value" and "Maximum Value". These values select the range of the input variable. If desired, these values may be changed, but please note the units of the input variables are printed after the input boxes. (Be careful not to enter MHz in a GHz field or vice-versa). Under these boxes, there is a dropbox and an edit box. If the dropbox is set to "Iterations", then the edit box will be the number of points the graph will have. If the dropbox is set to "Increments", then the edit box is used to define the accuracy of the graph's independent variable. For example, if the minimum value is 0 and the maximum value is 100, then selecting .5 increments will create a graph with 200 points (100-0)/.5. It is not recommended to try to create plots with over 1000 points. For 3-D graphs, 32 points for each variable would produce over 1000 points overall, so be especially careful to not specify too many points when creating 3-D graphs. A progress indicator will be visible in the lower left corner of excel.

This is an example of a 3-D graph of Total Gaseous Attenuation vs Frequency and Pressure:



On the new workbook, you will notice that the graph is on a sheet with the tab labeled "Graph", and similarly there is a tab labeled data for the sheet containing data that produced the graph. If you click on this, you will have access to the data that the graph is using. If you modify this data, the graph will update accordingly. If you delete this sheet of data, the graph will be blank, and an error may occur. If you create several graphs, they will all be put in the same workbook and the names of the graphs will progress from "Graph" to "Graph 2" and "Graph 3". The new graphs will not write over or modify the old ones. To delete a graph, click on the tab, then go to the menu option "edit" and "Delete Sheet". You may save and load these graphs and data since they are regular spreadsheets.

Gaseous Attenuation

This model is based on a simplified algorithm for quick, approximate estimation of gaseous attenuation. This includes the effects of attenuation due to both Oxygen and Water Vapor. It is only considered valid between 1 and 350 GHz and for elevation angles between 0° and 90°.

This model is taken from:

"Propagation Effects Handbook for Satellite Systems Design (Fifth Edition) by Luis J. Ippolito", pp. 6-13

This model can be used in a worksheet or programming module using the following format:

> =Gaseous_Attenuation(Frequency, Pressure, Temperature, Rho, H1, H2, Theta, Re, Satellite, Weather, Optional selector)

- Frequency- of the transited signal. Measured in GHz
- Pressure- air pressure measure in hPa
- Temperature- of the air in °C
- Rho-Water Vapor Density (Normally 7.5 g/m^3)
- H1- Height of First Ground Station (km)
- H2- Height of Second Ground Station (km)
- Theta- Elevation angle (degrees from Horizontal)
- Re- The modified Earth Radius (Normally 8500 km)
- Satellite-0 for a Ground Station-Ground Station, 1 for Ground Station-Satellite Station
- Weather-0 for Clear Weather conditions, 1 for Rainy weather
- Selector- a number used to select one of the following:
  1. AlphaO - Specific Attenuation Due to Oxygen
  2. AlphaW - Specific Attenuation Due to Water
  3. Ho - The equivalent height for dry air
  4. Hw - The equivalent height for water vapor
  5. A - Total Gaseous Attenuation

Example:

=Gaseous_Attenuation(20, 1000, 20, 7.5, 0.1, 10, 80, 8500, 1, 1, 4) would return the Equivalent Height for Water Vapor for a 10 GHz

Scintillation Model

Scintillation is the rapid fluctuation of the signal amplitude due to the small-scale refractive index inhomogeneities in the troposphere. Scintillation intensity depends on temperature, humidity, path elevation angle and frequency.

This model is taken from:

"Propagation Effects Handbook for Satellite Systems Design (Fifth Edition) by Louis J. Ippolito", pp. 126-128

This model can be used in a worksheet or programming module using the following format:

=ITUR_Scint(Temp, He, Theta, hL, Freq, D, Eta, P, Optional selector)

- Temp- Temperature in Celsius
- He- Relative Humidity (%)
- Theta- Elevation Angle (Degrees from Horizontal)
- hL- Height of Turbulent Layer (default=1000m)
- Freq- Frequency (GHz)
- D- Geometrical Antenna diameter (m)
- Eta- Antenna Efficiency (%)
- P- Percentage of time of fade exceedance
- Optional Selector- One of the following:
  1. Es - Saturation Vapor Pressure (mb)
  2. Nwet - Wet term of radio refractivity
  3. Sigma ref - Standard Deviation of signal amplitude
  4. L - Effective Path Length (km)
  5. Deff - Effective Antenna Diameter (m)
  6. G - Antenna Averating Factor
  7. Sigma - Standard deviation of signal amplitude
  8. Ap - Attenuation exceeded p% of the average year

Example:

=ITUR_Scint(20, 10, 80, 1, 20, 5, 55, 1, 10) would return the saturation vapor pressure

Attenuation Frequency Scaling Model

The ratio of fades (in dB) is approximately consistent with the ratio of the square root of frequencies.

Several Models are available for frequency scaling. Instead of choosing just one, five models are made available in this program.

These models are taken from:

"Propagation Effects Handbook for Satellite Systems Design (Fifth Edition) By Louis J. Ippolito", pp. 185-190

1. ITUR Frequency Scaling Model
2. CCIR Frequency Scaling Model
3. Simple Frequency Scaling Model
4. Battest Frequency Scaling Model
5. Average of Previous Models

This model can be used in a worksheet or programming module using the following format:

=ITUR_Scal_Calc(Freq1, Freq2, Ap, Optional selector)

Freq1- Frequency being scaled from (GHz)
Freq2 - Frequency being scaled to (GHz)
Ap - Attenuation being scaled (dB)
Optional Selector- A number selecting which model you wish to use:

1. ITUR
2. CCIR
3. Simple
4. Battest
5. Average

Example:

=FreqAttScal(1,10,10,1) would return ITUR model

Cumulative Distribution of Fade Duration Model

This model gives the probability of fade duration given that the attenuation exceeds a 5 dB threshold level.

This model is taken from:

> "Propagation Effects for Land Mobile Satellite Systems: Overview of Experimental and Modeling Results", NASA Reference Publication 1274, February 1992, by Julius Goldhirsh and Wolfhard J. Vogel, pp. 41-46.

This model can be used in a worksheet or programming module using the following format:

> =CumDistFadeDur (Alpha, Sigma, dd, Optional selector)

- Alpha - Angle of Incidence (deg) (default=.22)
- Sigma - Standard Deviation of ln(dd) (default=1.215)
- dd - Fade Duration Range (m)
- Optional selector - Probability of Fade Duration (%)

Example:

> =CumDistFadeDur (0.22,1.215,0.5,1) would return Probability of Fade Duration

Diffusely Scattered Waves Model

Transmission from the satellite illuminates all the scatters around the moving vehicle and the scattered waves arrive at the mobile antenna with random amplitude, phase, polarization, delay and Doppler Shifts. The received waveform is limited to a band of frequencies relative to the zero speed center frequency and is given by the |Doppler Shift| model below:

This model is taken from:

"Propagation Effects for Land Mobile Satellite Systems: Overview of Experimental and Modeling Results", NASA Reference Publication 1274, February 1992, by Julius Goldhirsh and Wolfhard J. Vogel, pp. 76.

This model can be used in a worksheet or programming module using the following format:

=DiffScat (Frequency, Velocity, Optional selector)

- Frequency- Measured in MHz
- Velocity- Measured in Km/Hr
- Optional selector - Absolute Doppler Shift (Hz)

Example:

=DiffScat (10,100, 1) would return the Absolute Doppler Shift

Empirical Roadside Shadowing Model

The ERS model corresponds to an overall average driving condition encompassing right and left lane driving and opposite directions of travel along highways and rural roads where, the overall aspect of the propagation path was for the most part orthogonal to the lines of roadside trees and utility poles. The dominant cause of LMSS signal attenuation is due to canopy shadowing, where multipath fading plays only a minimal role. The reasonable resultant fit is given by the ERS model.

This model is taken from:

> "Propagation Effects for Land Mobile Satellite Systems: Overview of Experimental and Modeling Results", NASA Reference Publication 1274, February 1992, by Julius Goldhirsh and Wolfhard J. Vogel, pp. 16-23.

This model can be used in a worksheet or programming module using the following format:

=EmpRoadShadow(Percentage, Theta, Optional selector)

- Percentage- Percentage of the distance traveled over which the fade is exceeded
- Theta- Path Elevation Angle (deg)
- Optional selector – Fade: Empirical Roadside Fade (dB)

Example:

=EmpRoadShadow(10,60,1) would return the Empirical Roadside Fade for path elevation of 60 deg.

Faraday Rotation Model

Faraday rotation effects are potential contributors to signal strength variations, which can be neglected for Land Mobile Satellite Systems (LMSS) which employ circular polarization. The ionosphere contains free electrons in a relatively static magnetic field. This combination (for Freq. > 100 MHz) causes polarization rotation of linearly polarized waves as given by Phi, in the equation below:

This model is taken from:

> "Propagation Effects for Land Mobile Satellite Systems: Overview of Experimental and Modeling Results", NASA Reference Publication 1274, February 1992, by Julius Goldhirsh and Wolfhard J. Vogel, pp. 77.

This model can be used in a worksheet or programming module using the following format:

=FaradayRot(Be, TEC, Freq, Optional selector)

- Be - Earth's Magnetic Field (Wb/m^2) (default = 0.000043)
- TEC - Total Electron Content ($\#/m^2$) (default = 1.68 E 18)
- Freq - Frequency (MHz) (Must be >100)
- Optional selector – Phi: Polarization Rotation (deg)

Example:

=FaradayRot(.000043,1.68E18,870,1) would return the Polarization Rotation model.

Fresnel Zone Model

Constructive or destructive interference caused by an obstruction between the transmitter and receiver can be computed in terms of Fresnel Zones. This model produces different Fresnel zone radii, which can be used to compute the resultant field at the receiver.

This model is taken from:

> "Propagation Effects on Satellite Systems at Frequencies Below 10 GHz. A Handbook for Satellite Systems Design", NASA Reference Publication 1108(02), December 1987, by Warren L. Flock, Appendix 2.1, pp. 2-66,2-67.

This model can be used in a worksheet or programming module using the following format:

> =Fresnel(Freq, dist1, dist2, n, Optional selector)

- Freq - Frequency (Mhz)
- dist1 - Transmitter to Obstruction distance (m)
- dist2 - Obstruction to Receiver distance (m)
- n - which Fresnel Zone
- Optional selector – F(n): Fresnel Zone Radius

Example:

> =Fresnel(10,1000,100,1,1) would return the Fresnel Zone Radius

Frequency Reuse Model

This model computes the Cross-Polar Isolation (CPI) level at a given probability of fade exceedance. CPI is the ratio of the power in the co-polar component over the power in the cross-polar component at a fixed probability. An experiment in Australia suggests that the simultaneous employment of orthogonal signals as a means of frequency reuse is not feasible when fading in the co-polar component exceeds about 12 dB.

This model is taken from the "Propagation Effects for Land Mobile Satellite Systems: Overview of Experimental and Modeling Results", NASA Reference Publication 1274, February 1992, by Julius Goldhirsh and Wolfhard J. Vogel, pp. 52.

This model can be used in a worksheet or programming module using the following format:

=FreqReuse(A, Optional selector)

- A - Co-polarization Fade (dB)
- Optional selector – CPI: Ratio of Signal levels in co-polar component over cross-polar component(dB)

Example:

=FreqReuse(15.5,1) would return the Cross-Polar Isolation level for a co-polarization fade of 15.5 dB.

Diversity Improvement Model

The diversity improvement factor is the ratio of the single-terminal probability distribution at the fade depth, A, to the two terminal probability at the same attenuation level.

This model is taken from:

"Propagation Effects for Land Mobile Satellite Systems: Overview of Experimental and Modeling Results", NASA Reference Publication 1274, February 1992, by Julius Goldhirsh and Wolfhard J. Vogel, pp. 56-58.

This model can be used in a worksheet or programming module using the following format:

=DivImp(A, d, Optional selector)

- A - Fade Depth (dB)
- d - Antenna Separation (m)
- Optional selector - DIF- Least square Estimate of Diversity Improvement Factor

Example:

=DivImp(10,100,1) would return the Diversity Improvement Factor at the fade depth of 10 dB and an antenna spacing of 10 m.

Rayleigh Model

This model calculates the Rayleigh probability density function.

This model is taken from:

> "Propagation Effects on Satellite Systems at Frequencies Below 10 GHz. A Handbook for Satellite Systems Design", NASA Reference Publication 1108(02), December 1987, by Warren L. Flock, pp. 6-23.

This model can be used in a worksheet or programming module using the following format:

> =Rayleigh(Alpha, Z, Optional selector)

- Alpha - Mean Value of the Distribution
- Z - Probability Density of the total field intensity amplitude
- Optional selector – P: Rayleigh Probability density

Example:

> =Rayleigh(10,10,1) would return the Rayleigh Probability density

Reflection Coefficient Model

This model calculates the reflection coefficients, RhoH, RhoV, RhoC, and RhoX, from a smooth reflecting surface for horizontal, vertical, copolar, and cross polarizations.

This model is taken from:

> "Propagation Effects on Satellite Systems at Frequencies Below 10 GHz. A Handbook for Satellite Systems Design", NASA Reference Publication 1108(02), December 1987, by Warren L. Flock, pp. 6-13 to 6-17.

This model can be used in a worksheet or programming module using the following format:

> =ReflectCoeff(Freq, Reg_Surf, Theta_, Optional selector)

- Frequency - One of the following:
  1. 2 GHz- S Band
  2. 8 GHz- X Band
  3. 30 GHz- K Band
- Regional Surface - On of the following:
  1. Sea Water
  2. Wet Ground
  3. Medium Dry Ground
  4. Very Dry Ground
- Theta - Elevation Angle (deg)
- Optional selector - One of the following:
  1. K – Relative Dielectric Constant
  2. RhoV – Vertical Polarization
  3. RhoH – Horizontal Polarization
  4. RhoC – Circular Polarization
  5. RhoX – Cross Polarization

Example:

> =ReflectCoeff(1,3,60,5) would return the Cross Polarization for a 2 GHz signal over Medium-Dry Ground

Fading Due to Sea Reflection Model

This model provides an estimate of multipath fading due to sea reflection. It is only applicable in the frequency range from 1 to 2 GHz and for elevation angles of 3 degrees or higher. Furthermore, the antenna radiation pattern in the direction midway between the point of specular reflection and the horizon must be larger than negative 10 dB.

This model is taken from:

> "International Telecommunication Union, 1992 - CCIR Recommendations, Propagation in Non-Ionized Media", Geneva,
> 1992, Rec. 680-1, pp.270-1.

This model can be used in a worksheet or programming module using the following format:

=SeaReflectFade(Theta, Gm, Surface, Frequency, Polarization, P, Optional Selector)

- Theta- Elevation Angle (deg)
- Gm- Maximum Antenna Gain (dB)
- Surface - One of the following:
    1. Sea Water (20 deg)
    2. Fresh Water (20 deg)
    3. Pure Water (20 deg)
    4. Ice
- Frequency - One of the following:
    1. 1.0 GHz
    2. 1.5 GHz
    3. 2.0 GHz
- Polarization - One of the following:
    1. Horizontal
    2. Vertical
    3. Circular
- Percentage of time amplitude is exceeded(P) - Must be one of the following:

1. 0.001	7. 30	13. 90	19. 99.9
2. 0.01	8. 40	14. 95	20. 99.95
3. 0.1	9. 50	15. 98	21. 99.98
4. 1.0	10. 60	16. 99	22. 99.99
5. 10	11. 70	17. 99.5	23. 99.995
6. 20	12. 80	18. 99.8	24. 99.998

- Selector- One of the following:
    1. G- Relative Antenna Gain Midway between the horizon and the point of specular reflection (dB)
    2. Rh- Reflection Coefficient for Horizontal Polarization
    3. Rv- Reflection Coefficient for Vertical Polarization
    4. Rc- Reflection Coefficient for Circular Polarization
    5. C(theta)- Correction Factor (dB)
    6. Pr (dB)
    7. Fading Depth (dB)

Example:

=SeaReflectFade(5,10,1,1,1,3,1) would return the relative antenna Gain (G) for 0.1 polarization.

Interference Prediction Method

Interference in adjacent satellite systems may occur in the uplink or downlink. Also, the operation of the multi-spot-beam systems can cause interference between beams of the same frequency. This model calculates the signal-to-noise ratio, interference-to-noise ratio, and signal-to-noise-plus-interference ratio of the received signal.

This model is taken from:

> "International Telecommunication Union, 1992 - CCIR Recommendations, Propagation in Non-Ionized Media", Geneva,
> 1992, Rec. 680-1, pp.274-5.

This model can be used in a worksheet or programming module using the following format:

=InterferPredict(d, D/M, D/N, D/I, I_D/I_M, Pa, Optional Selector)

- D – Power of Direct Desired Signal
- D/M – Power of Reflected Desired Signal
- D/N – Average Power of System Noise
- D/I – Median Value of Interference Signal
- I_D/I_M – Power of Direct Interference Signal Divided By Power of Reflected Interference Signal
- Pa – Availability Time Percentage. Must be one of the following:
    1. 50
    2. 80
    3. 90
    4. 95
    5. 99
    6. 99.5
    7. 99.9
    8. 99.99
- Optional Selector - Must be one of the following:
    1. C/N - Signal to Noise Ratio
    2. C/I - Signal to Interference Ratio
    3. C/(N+I) - Signal to Noise and Interference Ratio

Example:

= InterferPredict(5,5,7,15,20,1,1) would return the Signal to Noise Ratio

Altshuler Fog Model

This model was designed in 1984, and came to be known as the Altshuler Model. It was developed using fog attenuation data over the range of 10 to 100 GHz and -8 to 25°C. However, the author recommends that the procedure should not be used for frequencies below 30GHz since the error is comparable in magnitude to the fog attenuation itself

This model is taken from:

> "Propagation Effects Handbook for Satellite Systems Design (Fifth Edition) by Louis J. Ippolito", pp 56-57

This model can be used in a worksheet or programming module using the following format:

=Fog_Calc(Frequency, Temperature, Visibility, Extent, Optional selector)

- Frequency - of the transmitted signal (GHz)
- Temp - Temperature (°C) (0 for clouds or ground temp for fog)
- Visibility - measured in km
- Extent - measured in km
- Optional Selector - a number used to select one of the following:
  1. Normalized Fog Attenuation (dB/km/g/m^3)
  2. Fog Density (g/m^3)
  3. Total Fog Attenuation (dB)

Example:

=Fog_Calc(50, 20, 0.1, 2.1, 3) would return Total Fog Attenuation

ITUR Cloud Model

This model can be used to calculate the attenuation along an RF Earth-space path for both clouds and fog.

This model is taken from:

"Propagation Effects Handbook for Satellite Systems Design (Fifth Edition) by Luis J. Ippolito", pp 43-45

This model can be used in a worksheet or programming module using the following format:

=Cloud_Calc(Frequency, Temp, ElevAng, RhoL, Optional selector)

- Frequency- of the transmitted signal (GHz)
- Temp- Temperature (°C) (0 for clouds or ground temp for fog)
- ElevAng- Elevation Angle (deg)
- RhoL- Water content of clouds (g/m^3) (default = 1)
- Optional Selector- a number used to select one of the following:
  1. Fp - Primary Relaxation Frequency
  2. Fs - Secondary Relaxation Frequency
  3. E' - Complex dielectic permittivity of water
  4. E"- Complex dielectic permittivity of water
  5. K - Specific Attenuation Coefficient (dB/km)/(g/m^3)
  6. A - Total Attenuation due to clouds(dB)

Example:

=Cloud_Calc(20,0,90,7.5,6) would return the Total Attenuation Due to Clouds

Radio Noise Model

This model calculates the noise, brightness temperature and attenuation from source temperature, effective temperature of absorbing region and optical depth.

This model is taken from:

"Propagation Effects on Satellite Systems at Frequencies Below 10 GHz. A Handbook for Satellite Systems Design", Nasa
Reference Publication 1108(02), December 1987, by Warren L. Flock, pp. 5-11.

This model can be used in a worksheet or programming module using the following format:

=Noise(Ts, Ti, Tau, Optional Selector)

- Ts - Source Temperature (Kelvins)
- Ti - Effective Temperature of absorbing region (Kelvins)
- Tau - Optical Depth (km)
- Optional Selector - One of the following:
    1. Tb - Brightness Temperature (Kelvins)
    2. A - Attenuation (dB)

Example:

= Noise_calc(10,25,5,2) would return the Attenuation for Tau of 10km

ITUR Model

This Rain Model is the most widely accepted model by the international propagation community. It was first accepted globally in 1982 and is continuously updated as rain attenuation modeling is better understood

This model is taken from:

> "Propagation Effects Handbook for Satellite Systems Design (Fifth Edition) by Louis J. Ippolito", pp 59-67

This model can be used in a worksheet or programming module using the following format:

=ITUR_Rain_Calc(Lat, Hs, Theta, Re, Zone, Tau, Freq, Perc, Optional Selector)

- Lat - Station's Latitude (deg)
- Hs - Height above mean sea level of Earth station (km)
- Theta - Elevation Angle (deg)
- Re - Modified Earth Radius (default = 8500)
- Zone - Climatic Zone. Must be one of the following:

1. A	5. E	9. J	13. N
2. B	6. F	10. K	14. P
3. C	7. G	11. L	15. Q
4. D	8. H	12. M	

- Tau- Polarization Tilt (degrees)
- Freq- Frequency (GHz) (must be between 0 and 30)
- Prec- Percentage of attenuation exceeded in an average year (%)
- Optional Selector- a number used to select one of the following:
  1. hR- Effective Rain Height (km)
  2. Lg - Horizontal Projection of slant path length (km)
  3. R(0.01) - Rain Intensity Exceeded for 0.01% of an average year (mm/hr)
  4. r(0.01) - Reduction Factor
  5. Yr - Specific Attenuation using the frequency dependent coefficient (dB/km)
  6. A(0.01) - Attenuation Exceeded for 0.01% of an average year
  7. Ap - Attenuation exceeded for p% of an average year

Example:

> =ITUR_Rain_Calc(30, .1, 80, 8500, 4, 45, 20, 1, 6) would return the attenuation exceeded .01% of the average year

COMSAT Model

This is a proposed amendment to the CCIR slant-path rain attenuation prediction procedure, to improve the prediction accuracy in all rain climates. This amendment considers modification of horizontal path reduction factor, vertical path reduction factor, probability distribution of path attenuation.
This model is taken from:

This model is taken from:

> "Proposed Amendment of Recommendation 618 of Rain Attenuation", by Asoka Dissanayake, the CCIR Study Groups (Document USSG5C/1T, October 1992)

This model can be used in a worksheet or programming module using the following format:

=Comsat_(Phi, hS, Theta, Re, Freq, Tau, CZone, P, Optional Selector)

- Phi - Absolute Value of Station Latitude (deg)
- HS - Station's Height (km)
- Theta - Elevation Angle (deg)
- Re - Modified Earth Radius (km) (default = 8500)
- Freq - Frequency (GHz)
- Tau - Polarization Tilt Angle. Must be one of the following:
  - 0 deg - Vertical Polarization
  - 45 deg - Circular Polarization
  - 90 deg - Horizontal Polarization
- Czone - Climatic Zone. Must be one of the following:

A	E	J	N
B	F	K	P
C	G	L	Q
D	H	M	

- P- Percentage Probability of Interest
- Optional Selector- Must be one of the Following:
  1. hfr - freezing height during rain
  2. Ls - Slant path length below freezing
  3. Lg - Horizontal Projection of path Length
  4. R(0.01) - Rain Intensity Exceeded for 0.01% of an average year (mm/hr)
  5. Gamma - Specific Attenuation (dB/km)
  6. rh(0.01) - Horizontal Path Adjustment factor
  7. Lr - Adjusted Rainy path length through rain (km)
  8. rv(0.01) - Vertical Reduction factor for 0.01
  9. Le - Effective Path length (km)

10. A(0.01) - Attenuation exceeded for 0.01% of an average year
11. Ap - Attenuation to be exceeded for P percentage of an average year (dB)
12. Ap/A(0.01) - Ratio of Ap divided by A(0.01)

Example:

=Comsat_(25,34,30,8500,25,0,3,0.1,1) would return the freezing height during rain for climate zone C

DAH(USA) Model

The DAH rain model is an extension to the ITU-R model, and is often referred to as the USA model. A copy of it can be found in "Propagation Effects Handbook for Satellite Systems Design by Dr. Louis Ippolito, or in open literature (Dissanayke, et al, 1997)

This model is taken from:

"Propagation Effects Handbook for Satellite Systems Design (Fifth Edition) by Louis J. Ippolito", pg 86-89

This model can be used in a worksheet or programming module using the following format:

=DAH_Calc(Phi, Hs, Theta, Re, Freq, Zone, Tau, P, Optional selector)

- Phi- Latitude (deg)
- Hs - Earth Station Elevation (km)
- Theta - Elevation Angle (deg)
- Re - Effective Earth Radius (km) (default =8500 km)
- Freq - Frequency (GHz)
- Zone - Rain Climate Region. This is used to calculate the rain rate exceeded for .01% of the average year. May be one of the following, or the user may enter a rain rate (greater than 12 mm/hr) instead.

1. A	5. C	9. E
2. B1	6. D1	10. F
3. B	7. D or D2	11. G
4. B2	8. D3	12. H

- Tau - Polarization Tilt Angle (deg)
- P- Proabability of occurrence
- Optional Selector - a number used to select one of the following:
    1. hR - Rain Height (km)
    2. Ls - Slant Path Length(km)
    3. Lg - Horizontal Projection Length (km)
    4. yR - Specific Attenuation
    5. rh0.01 - Horizontal Path Adjustment factor
    6. Lr - Adjusted Rain Path Length (km)
    7. rv001 - Vertical Path Adjustment Factor
    8. Le - Effective path length through rain (km)
    9. A0.01 - Attenuation exceeded for .01% of an average year (dB)
    10. Ap - Attenuation exceeded for p% of an average year (dB)

Example:

=DAH_Calc(20, .1, 80, 8500, 20, 110, 45, .1, 9) would return the Attenuation exceeded .1% of the time in a region where the rain rate of 110 mm/hr is exceeded .01% of the average year.

Depolarization Model

Depolarization is a change in the polarization state of the signal due to the troposphere on an Earth-space link. It is measured by a parameter called cross polarization discrimination (XPD): the ratio of power in the copolar component over the power in the cross polar component. This model gives XPD due to rain and XPD due to both rain and ice. Run the CCIR or Global models to obtain attenuation for a given p%.

This model is taken from:

Recommendation P.618-5 (1997) from the International Telecommunication Union

This model can be used in a worksheet or programming module using the following format:

=ITURDep_Calc(Freq, Ap, Tau, Theta, P, Sigma, Optional Selector)

- Freq - Frequency (GHz)
- Ap - Attenuation Exceeded (dB)
- Tau - Polarization Tilt Angle (deg)
- Theta - Elevation Angle (deg)
- P - Percentage of time attenuation is exceeded (%)
- Sigma - Standard deviation of the raindrop canting angle
  (Enter zero to use the default based on P)
- Optional Selector- Must be one of the following:
  1. Frequency Dependant Term
  2. Rain Attenuation Dependant Term
  3. Polarization Improvement Factor
  4. Elevation Angle Dependant Term
  5. Canting Angle Dependant Term
  6. Ice Crystal Dependant Term
  7. XPDp - Cross Polarization Discrimination

Example:

=ITURDep_Calc(20, 10, 90, 80, 1, 0, 7) would return the Cross Polarization Discrimination

Global Model

This model calculates the total path attenuation due to rain for all rain rate climate regions in the U.S. and Southern Canada.

This model is taken from:

> "Propagation Effects Handbook for Satellite Systems Design", NASA Reference Publication 1082(04), February 1989, by Louis J Ippolito, pp. 6-23 to 6-32.

This model can be used in a worksheet or programming module using the following format:

=GlobalRain(CZone, P, Lat, Hg, Freq, Theta, Tau, Optional Selector)

- CZone- Rain Climate Region. Must be one of the following:

1.A	5. C	9. E
2.B1	6. D1	10. F
3.B	7. D or D2	11. G
4.B2	8. D3	12. H

- P - Probability of occurrence
- Lat - Latitude (deg)
- Hg - Earth Station Elevation (km)
- Theta - Elevation Angle (deg)
- Freq - Frequency (GHz)
- Tau - Polarization Tilt Angle (deg)
- Optional Selector - One of the following:
  1.Rp - Rain Rate Distribution (mm/hr)
  2.Hr - Rain Height (km)
  3.D - Horizontal Projection Length (km)
  4.yR - Specific Attenuation
  5.Ap - Attenuation exceeds p% of the average year (dB)

Example:

=Global_Calc(12,10,15,1,60,20,45,3) would return Horizontal Projection Length for Zone H

Site Diversity Model

Site diversity is a technique used to improve overall link performance by taking advantage of the especially in homogeneous nature of rain. Ideally, two sites located in different places will not simultaneously experience equal rain attenuation. Therefore, by monitoring whichever signal is the less attenuated, overall system throughput is enhanced. While experiments are presently being conducted using three or more ground stations, models typically focus on a two-site configuration. Three models are available through this program:

- ITUR Site Diversity
- Hodge Site Diversity (1976)
- Hodge Site Diversity (1982)

These models are taken from:

> "Propagation Effects Handbook for Satellite Systems Design (Fifth Edition)
> By Louis J. Ippolito", PP 203-205

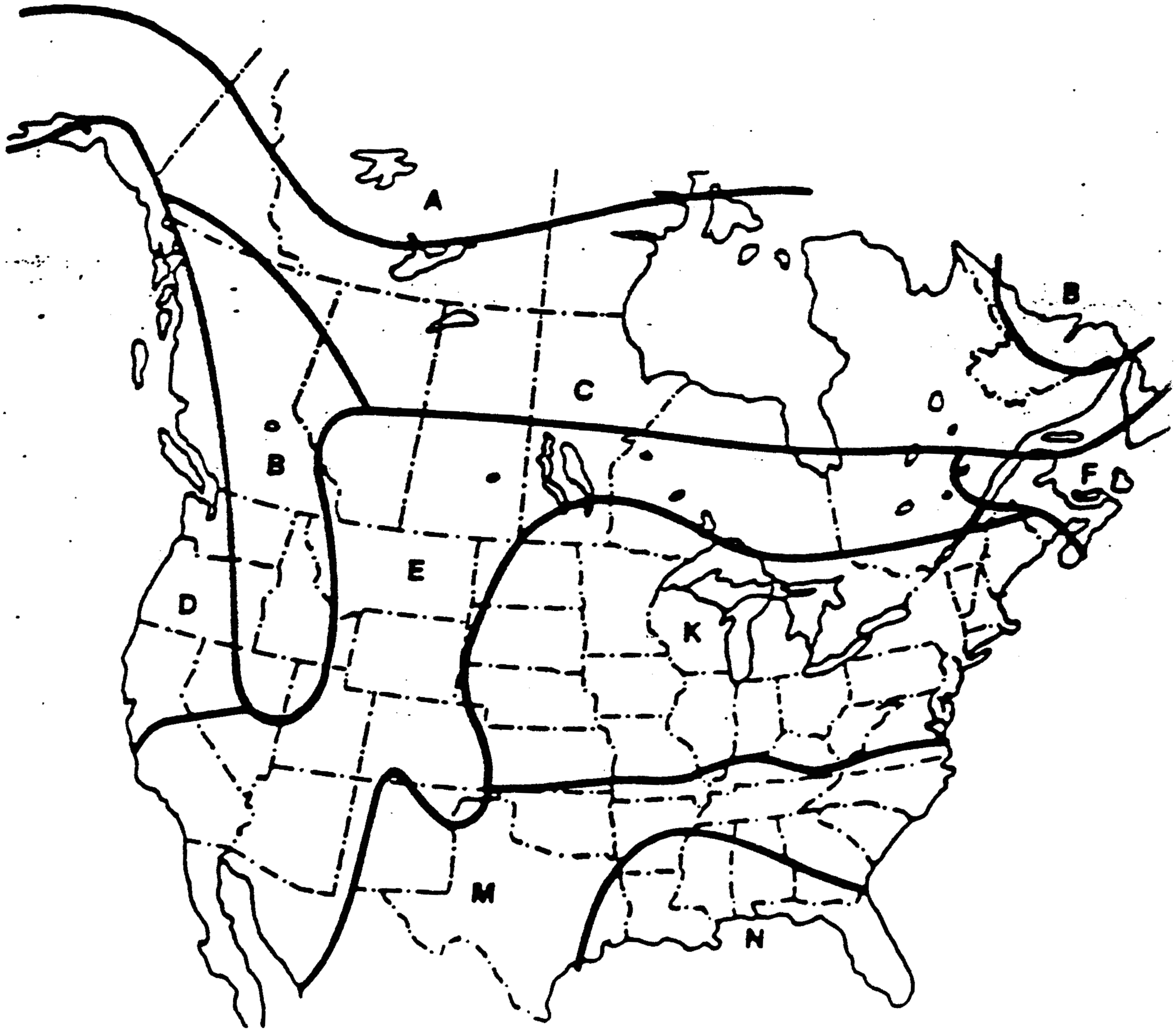
This model can be used in a worksheet or programming module using the following format:

=Site_Calc(A, D, Phi, Theta, Freq, Optional Selector)

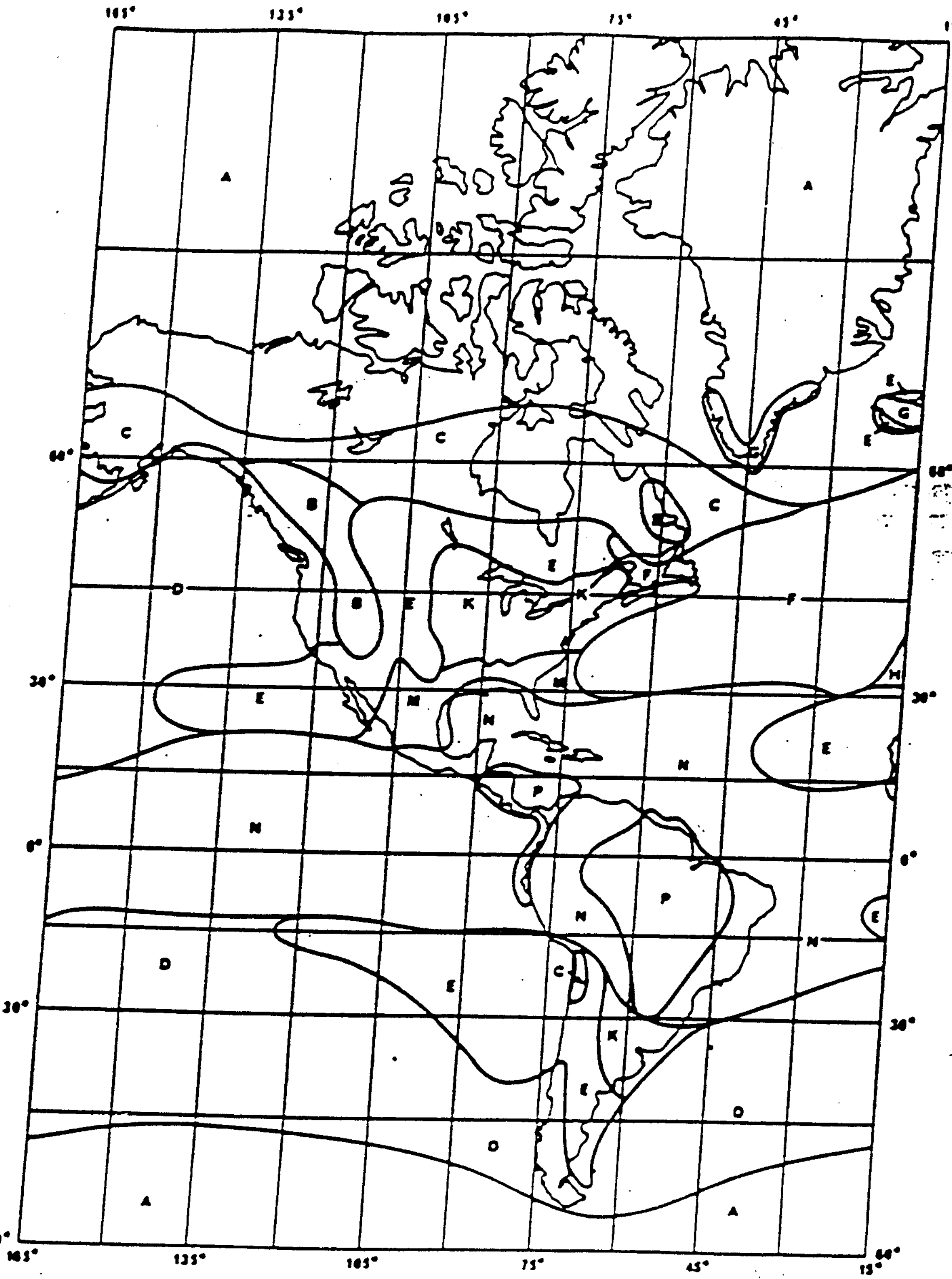
- A - Path rain Attenuation for a single frequency (dB)
- D - Separation between two sites (km)
- Phi - Azimuth Angle (deg)
- Theta - Elevation Angle (deg)
- Freq - Frequency (GHz)
- Optional Selector - One of the following:
  1. ITUR Site Diversity Model
  2. Hodge 1976 Model
  3. Hodge 1982 Model

Example:

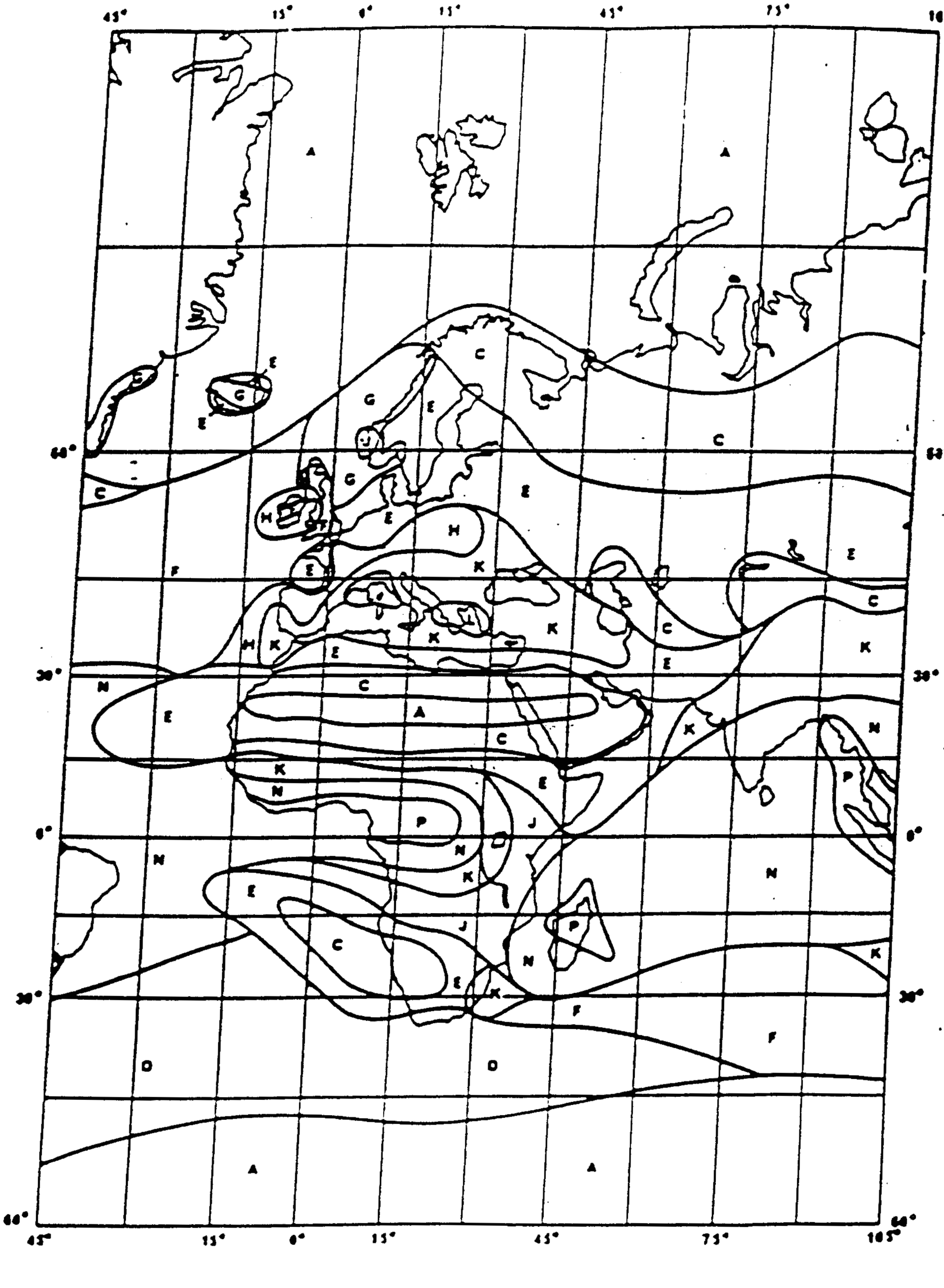
=Site_Calc(1,10,35,20,85,1) would return an ITUR Site Diversity Model



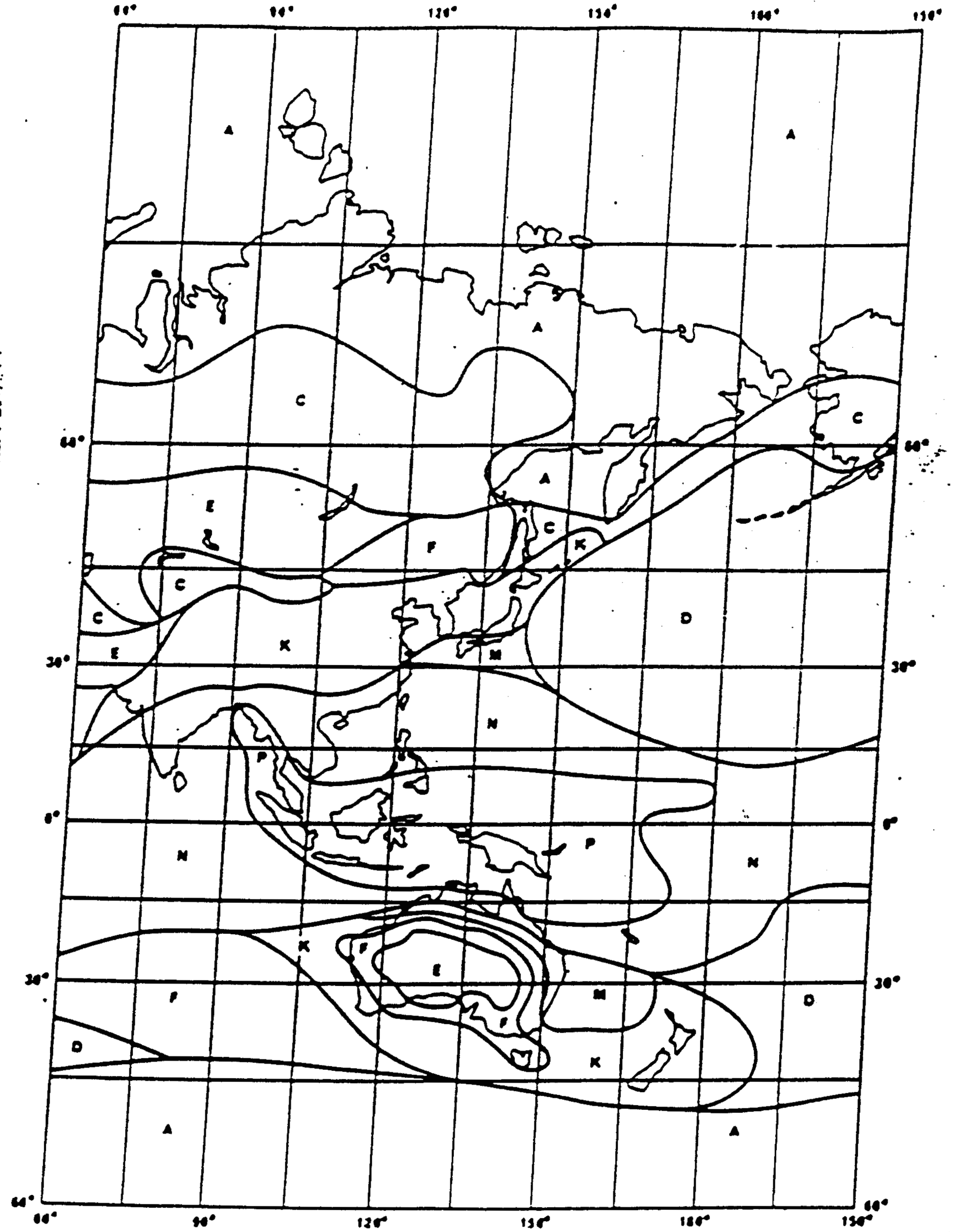
CCIR Rain Climatic Zones for the Continental United States and Canada



CCIR Rain Climate Zones (Sheet 1 of 3)



CCIR Rain Climate Zones (Sheet 2 of 3)



CCIR Rain Climate Zones (Sheet 3 of 3)